

PART A: MULTIPLE CHOICE
Value: 62.5% of the examination

Suggested Time: 80 minutes

INSTRUCTIONS: For each question, select the best answer and record your choice on the Answer Sheet provided. Using an HB pencil, completely fill in the bubble that has the letter corresponding to your answer.

You have Examination Booklet Form A. In the box above #1 on your Answer Sheet, fill in the bubble as follows.

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1. Which of the following would have the highest reaction rate at room temperature?

- A. $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightarrow 2\text{HI}(\text{g})$
 B. $\text{H}_2\text{S}(\text{g}) + \text{Cl}_2(\text{aq}) \rightarrow 2\text{HCl}(\text{aq}) + \text{S}(\text{s})$
 C. $\text{Ca}^{2+}(\text{aq}) + \text{C}_2\text{O}_4^{2-}(\text{aq}) \rightarrow \text{CaC}_2\text{O}_4(\text{s})$
 D. $\text{Mg}(\text{s}) + 2\text{H}_2\text{O}(\ell) \rightarrow \text{Mg}(\text{OH})_2(\text{aq}) + \text{H}_2(\text{g})$

2. Consider the following experimental results:

	Experiment 1	Experiment 2
Reactants	powdered Cu and HCl	chunk of Cu and HNO_3
Temperature	20°C	10°C
Concentration of acid	0.6 M HCl	0.4 M HNO_3
Rate	low	high

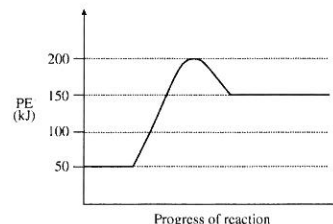
Which of the following factors would account for the lower rate in Experiment 1?

- A. temperature
 B. nature of reactants
 C. surface area of Cu
 D. concentration of acid

3. Which of the following describes "activation energy"?

- A. the amount of energy that product molecules possess
 B. the difference between the products PE and the reactants PE
 C. the amount of energy released when reactant molecules collide
 D. the minimum amount of energy required to start a chemical reaction

4. Consider the following PE diagram:



Which of the following is correct for the reverse reaction?

	PE (activated complex) (kJ)	ΔH (kJ)
A.	50	-100
B.	50	+100
C.	200	-100
D.	200	+100

5. Consider the following reaction mechanism:

Step 1:	$\text{ClO}^- + \text{H}_2\text{O} \rightarrow \text{HClO} + \text{OH}^-$
Step 2:	$\text{I}^- + \text{HClO} \rightarrow \text{HIO} + \text{Cl}^-$
Step 3:	$\text{HIO} + \text{OH}^- \rightarrow \text{IO}^- + \text{H}_2\text{O}$

Which of the following is correct?

	Reactant for the Overall Reaction	Reaction Intermediate
A.	I^-	OH^-
B.	ClO^-	H_2O
C.	H_2O	HClO
D.	HClO	HIO

6. Which of the following is correct for all systems at equilibrium?

I	The temperature is constant.
II	$[\text{Reactants}] = [\text{Products}]$
III	Forward and reverse reactions are occurring.
IV	The forward and reverse reaction rates are equal.

- A. I and II only
 B. I, III and IV only
 C. II, III and IV only
 D. III and IV only

7. In which of the following does entropy increase?

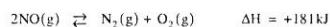
- A. the electrolysis of $\text{Na}_2\text{SO}_4(\text{aq})$
 B. the reaction of $\text{NaCl}(\text{aq})$ with $\text{AgNO}_3(\text{aq})$
 C. the redox reaction of an Fe nail in $\text{CuCl}_2(\text{aq})$
 D. the neutralization of $\text{Sr}(\text{OH})_2(\text{aq})$ by $\text{H}_2\text{SO}_4(\text{aq})$

8. Considering enthalpy and entropy factors, in which of the following will equilibrium be established?

I	$\text{Cl}_2(\text{g}) \rightleftharpoons \text{Cl}_2(\text{aq})$	$\Delta\text{H} = -25 \text{ kJ}$
II	$\text{CO}(\text{g}) + 2\text{H}_2(\text{g}) \rightleftharpoons \text{CH}_3\text{OH}(\text{g})$	$\Delta\text{H} = -91 \text{ kJ}$
III	$\text{Mg}(\text{s}) + 2\text{HCl}(\text{aq}) \rightleftharpoons \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g})$	$\Delta\text{H} = -425 \text{ kJ}$
IV	$3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g})$	$\Delta\text{H} = +2200 \text{ kJ}$

- A. I and II only
 B. II and IV only
 C. III and IV only
 D. I, II and III only

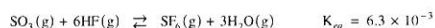
Use the following equilibrium to answer questions 9 and 10.



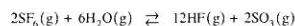
9. Which of the following pairs of stresses cause the same shift to the above equilibrium?
- adding a catalyst and decreasing volume
 - increasing pressure and increasing $[\text{NO}]$
 - decreasing $[\text{N}_2]$ and decreasing temperature
 - decreasing temperature and increasing volume
10. If some O_2 is injected into the above equilibrium system, which of the following is correct?

	Equilibrium Shift	Net Change $[\text{O}_2]$
A.	left	increase
B.	left	decrease
C.	right	increase
D.	right	decrease

11. Consider the following:



Which of the following is the value of K_{eq} for:



- 1.3×10^1
- 1.6×10^2
- 3.2×10^2
- 2.5×10^4

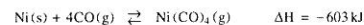
12. Consider the following:

I	$\text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g}) \rightleftharpoons \text{C}_2\text{H}_6(\text{g})$	$K_{\text{eq}} = 1.2 \times 10^{19}$
II	$2\text{HBr}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{Br}_2(\text{g})$	$K_{\text{eq}} = 7.0 \times 10^{-20}$
III	$\text{Si}(\text{s}) + \text{O}_2(\text{g}) \rightleftharpoons \text{SiO}_2(\text{s})$	$K_{\text{eq}} = 2.0 \times 10^{142}$

Which of the following lists these equilibria from the one that most favours products to the one that least favours products?

- I, II, III
- I, III, II
- II, III, I
- III, I, II

13. Consider the following equilibrium system:



Which of the following statements is correct?

- Increasing $[\text{CO}]$ will increase K_{eq} .
- Increasing temperature will increase K_{eq} .
- Increasing temperature will decrease K_{eq} .
- Decreasing $[\text{Ni}(\text{CO})_4]$ will decrease K_{eq} .

14. Consider the equilibrium:



A 1.0 L container is filled with 0.28 mol N_2 , 0.16 mol H_2 and 0.54 mol NH_3 .

In which direction will the reaction proceed and what will happen to the pressure of the system?

	Direction	Pressure
A.	left	decreases
B.	left	increases
C.	right	decreases
D.	right	increases

15. Which of the following will form a saturated solution?

- 0.10 mol CaSO_4 added to 1.0 L of water
- 0.10 mol Cs_2SO_4 added to 1.0 L of water
- 0.20 mol MgSO_4 added to 2.0 L of water
- 0.50 mol $\text{Pb}(\text{NO}_3)_2$ added to 2.0 L of water

16. Which of the following would be an appropriate measure of solubility?

- moles of solute per volume of solute
- mass of solute per volume of solution
- volume of solvent per mass of solvent
- moles of solute at a specific temperature

17. What is the complete ionic equation for the precipitation reaction between $\text{MgS}(\text{aq})$ and $\text{Sr}(\text{OH})_2(\text{aq})$?

- $\text{Mg}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{Mg}(\text{OH})_2(\text{s})$
- $\text{MgS}(\text{aq}) + \text{Sr}(\text{OH})_2(\text{aq}) \rightarrow \text{SrS}(\text{aq}) + \text{Mg}(\text{OH})_2(\text{s})$
- $\text{Mg}^{2+}(\text{aq}) + \text{S}^{2-}(\text{aq}) + \text{Sr}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) + \text{SrS}(\text{s})$
- $\text{Mg}^{2+}(\text{aq}) + \text{S}^{2-}(\text{aq}) + \text{Sr}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{Sr}^{2+}(\text{aq}) + \text{S}^{2-}(\text{aq}) + \text{Mg}(\text{OH})_2(\text{s})$

18. What is the K_{sp} expression for the low solubility salt formed when $\text{K}_2\text{SO}_3(\text{aq})$ and $\text{AlCl}_3(\text{aq})$ are mixed?

- $K_{\text{sp}} = [\text{SO}_3^{2-}]$
- $K_{\text{sp}} = [\text{K}^+][\text{Cl}^-]$
- $K_{\text{sp}} = [\text{Al}^{3+}]^2[\text{SO}_3^{2-}]^3$
- $K_{\text{sp}} = [\text{Al}^{3+}]^3[\text{SO}_3^{2-}]^2$

19. Which compound has the lowest solubility?

- ZnS
- CuS
- AgCl
- SrSO_4

20. What is the solubility of the salt PbCl_2 ?

- $1.4 \times 10^{-2} \text{ M}$
- $2.4 \times 10^{-3} \text{ M}$
- $3.5 \times 10^{-3} \text{ M}$
- $1.2 \times 10^{-5} \text{ M}$

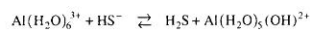
21. A solution is found to contain a $[\text{Pb}^{2+}]$ of 0.10 M. What is the maximum $[\text{SO}_4^{2-}]$ that can exist in this solution before a precipitate forms?

- $[\text{SO}_4^{2-}] = 1.8 \times 10^{-9} \text{ M}$
- $[\text{SO}_4^{2-}] = 1.8 \times 10^{-8} \text{ M}$
- $[\text{SO}_4^{2-}] = 1.8 \times 10^{-7} \text{ M}$
- $[\text{SO}_4^{2-}] = 1.3 \times 10^{-4} \text{ M}$

22. Which of the following represents the results of tests using an acidic solution?

	Reaction with Mg(s)	Colour in Phenol Red
A.	yes	yellow
B.	yes	red
C.	no	yellow
D.	no	red

23. Identify the reactant acid and its conjugate base in the equilibrium below.



	Reactant Acid	Conjugate Base
A.	HS^-	H_2S
B.	H_2S	$\text{Al}(\text{H}_2\text{O})_6^{3+}$
C.	$\text{Al}(\text{H}_2\text{O})_6^{3+}$	HS^-
D.	$\text{Al}(\text{H}_2\text{O})_6^{3+}$	$\text{Al}(\text{H}_2\text{O})_5(\text{OH})^{2+}$

24. Which of the following is the weakest acid?

- A. 0.10 M CH_3COOH
- B. 0.50 M HClO_4
- C. 1.0 M HIO_3
- D. 1.5 M HCN

25. Which of the following is the correct sequence of relative acid strengths?

- A. $\text{HO}_2^- > \text{HCO}_3^- > \text{H}_2\text{O}_2 > \text{H}_2\text{CO}_3$
- B. $\text{H}_2\text{CO}_3 > \text{HCO}_3^- > \text{H}_2\text{O}_2 > \text{HO}_2^-$
- C. $\text{H}_2\text{CO}_3 > \text{H}_2\text{O}_2 > \text{HCO}_3^- > \text{HO}_2^-$
- D. $\text{HCO}_3^- > \text{H}_2\text{O}_2 > \text{H}_2\text{CO}_3 > \text{HO}_2^-$

26. Water reacts most completely as an acid with which of the following?

- A. HO_2^-
- B. CO_3^{2-}
- C. $\text{C}_2\text{O}_4^{2-}$
- D. HPO_4^{2-}

27. Which of the following equations represents the ionization of water?

- A. $\text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_2(\text{aq}) + \frac{1}{2}\text{O}_2(\text{aq})$
- B. $2\text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{O}^{2-}(\text{aq})$
- C. $\text{H}_2\text{O}(\ell) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq})$
- D. $\text{H}_2\text{O}(\ell) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{OH}^-(\text{aq})$

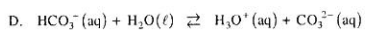
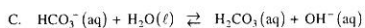
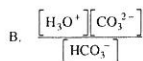
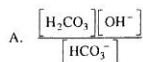
28. The ionization of water is endothermic. Which of the following is a suitable value of K_w if the temperature of water is lower than 25°C ?

- A. 6.8×10^{-15}
- B. 2.0×10^{-14}
- C. 1.0×10^{-14}
- D. 1.6×10^{-13}

29. What is the pOH of 0.30 M HI?

- A. 3.3×10^{-14}
- B. -0.52
- C. 0.52
- D. 13.48

30. What is the equilibrium constant expression for the predominant equilibrium in $\text{HCO}_3^-(\text{aq})$?



31. Which of the following 0.10 M solutions would have the lowest pH?

- A. HF
- B. NH_3
- C. HNO_3
- D. H_2CO_3

32. Which of the following describes the predominant hydrolysis reaction that occurs in $\text{Na}_2\text{HPO}_4(\text{aq})$?

- A. $\text{Na}_2\text{HPO}_4(\text{aq}) \rightleftharpoons 2\text{Na}^+(\text{aq}) + \text{HPO}_4^{2-}(\text{aq})$
- B. $\text{PO}_4^{3-}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{HPO}_4^{2-}(\text{aq}) + \text{OH}^-(\text{aq})$
- C. $\text{HPO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{PO}_4^{3-}(\text{aq})$
- D. $\text{HPO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_2\text{PO}_4^-(\text{aq}) + \text{OH}^-(\text{aq})$

33. Which of the following represents a basic salt solution?

- A. $\text{NaI}(\text{aq})$
- B. $\text{NH}_4\text{Cl}(\text{aq})$
- C. $\text{Na}_2\text{CO}_3(\text{aq})$
- D. $\text{NaHSO}_4(\text{aq})$

34. The term "equivalence point" typically applies to

- A. buffer solutions.
- B. titration reactions.
- C. saturated solutions.
- D. chemical indicators.

35. A solution is tested with two indicators and the following results are obtained:

Indicator	Colour
chlorophenol red	red
phenolphthalein	colourless

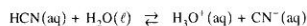
What is the approximate pH of the solution?

- A. 4.0
- B. 6.0
- C. 7.0
- D. 10.0

36. What is the net ionic equation for the reaction of hydrochloric acid with NaOH(aq)?

- A. $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\ell)$
- B. $\text{HCl}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\ell)$
- C. $\text{HCl}(\text{aq}) + \text{NaOH}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq}) + \text{OH}^-(\text{aq})$
- D. $\text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq}) + \text{Na}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq}) + \text{H}_2\text{O}(\ell)$

37. Consider the following buffer equilibrium system:



What is the net result of adding a small amount of KOH?

- A. The pH increases slightly.
- B. The pH decreases slightly.
- C. The [HCN] increases slightly.
- D. The [CN⁻] decreases slightly.

38. An oxide of which of the following elements will form a basic solution?

- A. P
- B. N
- C. K
- D. C

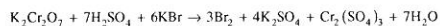
39. A reducing agent in a chemical reaction can best be described as a substance that

- A. loses electrons and has a decrease in oxidation number.
- B. gains electrons and has a decrease in oxidation number.
- C. loses electrons and has an increase in oxidation number.
- D. gains electrons and has an increase in oxidation number.

40. What happens to the oxidation number of O as MgO₂ undergoes a reaction in which H₂O₂ is formed?

- A. It decreases by 1.
- B. It increases by 1.
- C. It increases by 2.
- D. It does not change.

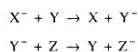
41. Consider the following redox equation:



Which chemical species is oxidized?

- A. Br in KBr
- B. S in H₂SO₄
- C. H in H₂SO₄
- D. Cr in K₂Cr₂O₇

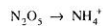
42. Consider the following spontaneous redox reactions:



Which of the following describes the relative strengths of the reducing agents?

- A. $\text{X}^- > \text{Y}^- > \text{Z}^-$
- B. $\text{Z}^- > \text{Y}^- > \text{X}^-$
- C. $\text{X}^- > \text{Y}^- > \text{Z}^-$
- D. $\text{Z}^- > \text{Y}^- > \text{X}^-$

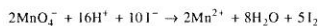
43. The following half-reaction can be balanced in acidic solution:



Which of the following appear in the balanced equation?

- A. 13e⁻
- B. 14e⁻
- C. 16e⁻
- D. 18e⁻

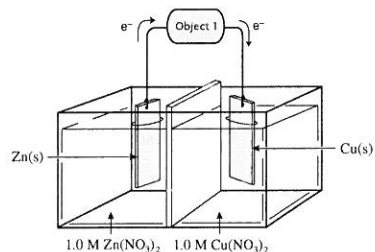
44. Consider the following redox reaction:



A 10.0 mL sample of an iodide solution is titrated with 15.7 mL of acidified 0.0106 M MnO₄⁻. What is the [I⁻] of the sample?

- A. $3.33 \times 10^{-3} \text{ M}$
- B. $1.66 \times 10^{-2} \text{ M}$
- C. $3.24 \times 10^{-2} \text{ M}$
- D. $8.32 \times 10^{-2} \text{ M}$

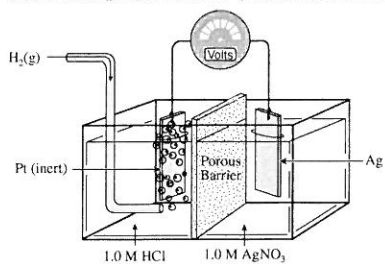
45. Consider the following diagram of a standard electrochemical cell:



Which of the following is correct?

	Object 1	Zn (s)
A.	light bulb	cathode
B.	light bulb	anode
C.	power supply	cathode
D.	power supply	anode

Use the following diagram to answer questions 46, 47 and 48.



46. What is the overall cell reaction?

- A. $\text{Ag}^+ + \text{H}^+ \rightarrow \text{H}_2 + \text{Ag}$
- B. $2\text{Ag} + 2\text{H}^+ \rightarrow 2\text{Ag}^+ + \text{H}_2$
- C. $2\text{Ag}^+ + \text{H}_2 \rightarrow 2\text{H}^+ + 2\text{Ag}$
- D. $\text{Ag}^+ + \text{H}_2 \rightarrow \text{Ag} + 2\text{H}^+ + \text{e}^-$

47. Which of the following is correct as the cell operates?

	Direction of NO_3^- Migration	pH near the Pt Electrode
A.	towards Pt	increases
B.	towards Pt	decreases
C.	towards Ag	increases
D.	towards Ag	decreases

48. Which of the following describes the direction of electron flow and the change in mass of the Ag electrode as the cell operates?

	Direction of Electron Flow	Mass of Ag Electrode
A.	from Pt to Ag	increases
B.	from Pt to Ag	decreases
C.	from Ag to Pt	increases
D.	from Ag to Pt	decreases

49. An iron pipeline can be protected from rusting by connecting it to a

- A. silver electrode buried beside the pipeline.
- B. copper electrode buried beside the pipeline.
- C. positive terminal of a direct current power supply.
- D. negative terminal of a direct current power supply.

50. The electrolysis of molten NaCl is an industrial process. What does the electrolysis produce?

- A. Na and Cl_2
- B. H_2 and O_2
- C. Na^+ and Cl^-
- D. NaOH and Cl_2

You have Examination Booklet Form A. In the box above #1 on your Answer Sheet, ensure you filled in the bubble as follows.

Exam Booklet Form/ Cahier d'examen	A	B	C	D	E	F	G	H
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This is the end of the multiple-choice section.
Answer the remaining questions in the Response Booklet.

PART B: WRITTEN RESPONSE

Value: 37.5% of the examination

Suggested Time: 40 minutes

1. (4 marks)

A student burned a paraffin candle ($C_{25}H_{52}$) in an open beaker according to the following equation:



The following data was recorded:

Time (min)	Mass of candle and beaker (g)
0.0	175.00
2.0	173.20

Calculate the rate of paraffin consumption in moles of $C_{25}H_{52}$ per minute (mol $C_{25}H_{52}$ /min); then, calculate how long it would take to produce 0.70 g CO_2 .

2. (4 marks)

Consider the following equilibrium:



Initially, 0.200 mol CO and 0.600 mol H_2 are placed in a 2.00 L container. At equilibrium, $[H_2O] = 0.039$ M. Calculate the value of K_{eq} .

5. (5 marks)

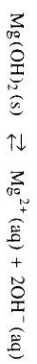
Aniline ($C_6H_5NH_2$) is a weak base with a $K_b = 4.3 \times 10^{-10}$.
Calculate the concentration of an aniline solution that has a pH = 8.80.
Begin by writing the equation for the predominant equilibrium.

6. (3 marks)

Calculate the $[OH^-]$ that results when 800.0 mL of 0.010 M HCl is mixed with 1.216 g $Sr(OH)_2$.
(Assume no volume change on mixing.)

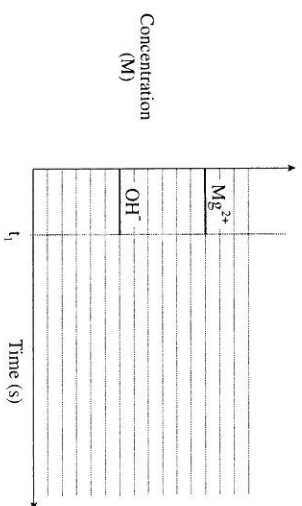
3. (4 marks)

Consider the following equilibrium:



What happens to the amount of solid $\text{Mg}(\text{OH})_2$ when some HCl is added? _____

On the graph below, sketch the effect of adding HCl at time t_1 .



4. (3 marks)

A solution of $\text{Sr}(\text{OH})_2(\text{aq})$ is titrated with H_2SO_4 .

Explain what will happen to the electrical conductivity during the titration.

Begin by writing the balanced formula equation, including states, to support your answer.

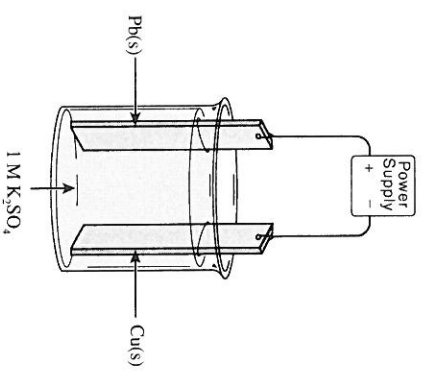
7. (4 marks)

Balance the following redox equation in acidic solution:



8. (3 marks)

Consider the following cell diagram:



Write the overall cell reaction.

Write the formula for a precipitate that forms as the cell operates.
